Method of Test for
CURING, CAPPING AND DETERMINING THE COMPRESSIVE STRENGTH OF MOLDED CONCRETE CYLINDERS
DOTD Designation: TR 230M/230-95

I. Scope

A. This method is to be used to cure, cap and determine the compressive strength of molded concrete cylinders.

B. Referenced Documents:
1. DOTD TR 226, Making, Field Curing and Transporting Concrete Test Specimens.
2. DOTD TR 227, Making and Curing Compressive Strength Specimens for Concrete Pipe.
3. AASHTO T 22, Compressive Strength of Cylindrical Concrete Cylinders.
4. AASHTO T 231, Capping Cylindrical Concrete Specimens.
5. AASHTO M 201, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes.

II. Apparatus

A. **Moist room** - shall conform to AASHTO M 201. The use of relative humidity recording devices is optional. When automatic relative humidity recording devices are not used, the relative humidity shall be measured and recorded weekly.

B. **Water storage containers** - shall conform to AASHTO M 201.

C. **Suitable absorbent fabric** - a fabric, such as burlap, having the capability of holding moisture for a suitable period of time.

D. **Sling psycometer or hygrometer** - for determining the relative humidity in moist rooms not equipped with a relative humidity recording device and for the periodic measurement and verification of relative humidity.

E. **Capping equipment**
1. For use with neoprene caps:
   a. **Two steel extrusion controllers** - conforming to AASHTO T 22.
   b. **Miscellaneous** - safety glasses or goggles, gloves, absorbent paper towels or cloth.
2. For use with sulfur mortar caps:
   a. **Alignment devices, capping plates, and melting pots** - conforming to AASHTO T 231.
   b. **Power vented hood** - to exhaust fumes to outdoors.
   c. **Small tools** - feeler gage, readable to 0.5 mm (0.02 in.), large metal ladle and a straightedge.
   d. **Thermometer** - dial type with metal stem with a minimum range of 10 to 150°C (50 to 400°F) and sensitive to 2°C (2°F).
   e. **Miscellaneous** - safety glasses or goggles, gloves, mineral oil and absorbent paper towels or cloths.

F. **Capping material**
1. **Neoprene caps** - conforming to AASHTO T 22.
2. **Sulfur mortar** - conforming to AASHTO T 231, except the minimum compressive strength of the mortar shall be 41.4 MPa (6000 psi) in 2 hours.

G. **Testing machine** - including upper and lower bearing blocks, shall conform to AASHTO T 22, except if equipped with a dial load gage, the dial shall be graduated in 2 kN (500 lb) increments or smaller. Each cylinder testing machine shall be equipped with a protective cage.
The testing machine shall be calibrated at least every 6 months for machines used for both acceptance and independent assurance samples and at least every 12 months for machines used for acceptance testing only.

H. **Measuring device** - caliper or micrometer readable to the nearest 0.25 mm (0.01 in.) and capable of measuring the diameter of the concrete cylinders at mid-height.

I. **Waterproof black ink marker.**

J. **Mold removal device** - capable of removing plastic molds without damaging the concrete cylinders.

K. **Small tools** - combination square, depth gage and steel ruler both readable to 1 mm (0.0625 in.). These tools are needed to check the ends of each cylinder prior to and after capping.

L. **Metal file, grinder, concrete saw** - for

planing the ends of concrete cylinders before testing.

M. **Worksheet** - Structural Concrete Tests, DOTD Form No. 03-22-0740 (Figure 1).

N. **Numbered field book** - for recording precast cylinder identification and test data.

III. Health Precautions

Proper ventilation is required when using sulfur mortar capping compounds due to the potentially hazardous fumes that could develop during heating. Capping compounds are hot molten liquids and can splatter and burn. Proper hand, arm, eye, face and footwear protection shall be used when working with capping compound.

Caution should be exercised when testing all concrete cylinders, especially when using neoprene caps; cylinders tested with neoprene caps are subject to shatter more intensely than cylinders tested with sulfur mortar caps. The protective cage on each testing machine shall be used.

IV. Sample

Cylinders shall be molded to have a diameter of 152.4 mm (6.0 in.) and a nominal height of 300 mm (12 in.). Field cure and transport the cylinders in accordance with TR 226 or TR 227.

V. Procedure

A. Specimen preparation

1. As soon as the cylinders are delivered to the laboratory, remove the rubber band and polyethylene bag or plastic cap from each cylinder.
2. Verify information marked on the side of the mold or top of each cylinder with the information entered on the worksheet or in the field book.
3. Transfer identifying information from the side of the mold to the top of the concrete cylinder before removing the mold.
4. Carefully remove the mold from each cylinder with the mold removal device without damaging the cylinder.
5. Examine and check each cylinder for condition. Damaged or improperly made cylinders shall not be tested.
6. Identify each cylinder by writing the laboratory number or sample number on the side of the cylinder with the black ink marker.
7. Cure in the following manner:
   a. Cast-in-place concrete for form removal and acceptance - within 30 minutes after removing the molds, store specimens in a moist room or storage container until the time of testing, except for early break cylinders that are to be capped and tested immediately.
   b. Precast concrete for form removal and acceptance - provide each cylinder with the same temperature and moisture environment as the structural member until time of test.

B. Determining the cross-sectional area.

1. Prior to capping, take the following steps:
   a. Verify information written on the top and side of each cylinder with the information entered on the worksheet or field book.
   b. Visually inspect each cylinder for damage. Damaged cylinders having projections or depressions on the ends greater than 3 mm (0.125 in.), out of round, out of plane or honey combed, etc. shall not be tested unless projections are corrected.
   c. Concrete cylinders shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 percent (3 mm, 0.12 in). This may occur during molding or when the single use molds are damaged or deformed during shipment.
   d. A cross-sectional area of 18,258 mm^2 (28.3 in^2) shall be used for all cylinders produced using 152.4 mm (6.0 in.) diameter molds, unless the mold was altered or damaged. Measure cylinders made using standard molds periodically to verify that cylinders are being produced with average diameters within a range of 152.4 ± 0.50 mm (6.0 ±

0.02 in.).

2. Should the cylinders have average diameters other than that required in step V.B.1.d, the cross-sectional area shall be determined as follows:
    a. Measure, to the nearest 0.25 mm (0.01 in.), two diameters of each cylinder, at right angles to each other at about mid-height of the cylinder.
    b. Calculate the average diameter to the nearest 0.25 mm (0.01 in.).
    c. Using the average diameter, determine the cross-sectional area (A) to the nearest 1 mm^2 (0.1 $in.^2$).

Note 1: *See Section VI for sample calculations.*

C. Capping
    1. Wipe the ends of the cylinders dry so that no free water or foreign matter remains on areas to be capped.
    2. For sulfur mortar, immediately cap the ends with sulfur mortar in accordance with AASHTO T 231. Sulfur mortar caps shall cure at least 2 hours prior to testing.
    3. Moist-cured cylinders shall be maintained in a moist condition between the completion of capping and the time of testing by returning them to moist storage or covering them with suitable moist absorbent fabric.
    4. For cylinders capped with sulfur mortar:
        a. Neither end of a capped concrete cylinder shall depart from perpendicular to the axis by more than 0.5° [approximately equivalent to a difference in height of 1.5 mm (0.0625 in.) for a 152.4 mm (6.0 in.) diameter cylinder]. If the capped cylinder appears to deviate from this tolerance, place the cylinder on a level surface and measure the angle of deviation by use of a combination square and steel ruler. Cylinders not meeting the tolerance shall not be tested unless the irregularity is first corrected.
        b. The surfaces of capped compression cylinders shall be plane within a tolerance of 0.05 mm (0.002 in.) across any diameter. During each day's capping operation, planeness of the caps on at least three cylinders representing the start, middle, and end of the run, shall be checked by means of a straightedge and feeler gage, making a minimum of three measurements on different diameters to ensure that the surfaces of the caps do not depart from a plane by more than 0.05 mm (0.002 in.).
        c. Caps should be about 3.0 mm (0.125 in.) thick, and in no instance shall any part of a cap be more than 8.0 mm (0.3125 in.) thick.
    5. For cylinders using neoprene caps: When the extrusion controller containing a neoprene cap is in place, neither end of the compression test cylinder shall depart from perpendicular to the axis by more than 2.0° [approximately equivalent to a difference in height of 5 mm (0.1875 in.) for a 152.4 mm (6.0 in.) diameter cylinders]. Cylinders not meeting this tolerance shall not be tested unless this irregularity is first corrected.

D. Determining compressive strength (do not use neoprene caps for acceptance testing of concrete with compressive strength below 10 MPa (1500 psi) or above 50 MPa (7000 psi).
    1. Testing cylinders using neoprene caps:
        a. The same surface of the neoprene cap shall bear on the concrete cylinder for all tests performed with that cap.
        b. Examine each neoprene cap for excessive wear or damage. Replace neoprene caps which have cracks or splits exceeding 10 mm (0.375 in.) in length regardless of depth. Insert the

neoprene caps in the steel extrusion controllers before they are placed on the cylinder.

c. Wipe the ends of the cylinder and the bearing face of each steel extrusion controller with an absorbent paper towel or cloth to remove any foreign matter.

d. Place the steel extrusion controllers, containing the neoprene caps, on the top and bottom surface of each concrete cylinder. No loose particles shall be trapped between the concrete cylinder and neoprene caps.

e. Visually inspect the cylinder to determine if the neoprene cap system is properly seated, centered on the cylinder, and the axis of the cylinder with cap is perpendicular as stated in step V.C.4. If the cylinder appears out of tolerance, measure the angle of deviation by use of the combination square and steel ruler. Cylinders not meeting the tolerance allowed shall not be tested unless this irregularity is first corrected.

f. Wipe clean the bearing faces of the upper and lower bearing blocks of the testing machine. Place the test cylinder on the lower bearing block and carefully align the axis of the cylinder with the center thrust of the spherically seated block.

g. Rotate the spherically seated block immediately prior to testing to assure freedom of movement. The blocks shall be designed to be rotated freely and tilted at least 4° in any direction.

h. Do not use a neoprene cap to test more than 100 cylinders.

2. Testing cylinders using sulfur-mortar caps:

a. Prior to positioning the cylinders in the machine, wipe the bearing faces of both blocks and the ends of the cylinders to remove any foreign matter which might interfere with testing operations.

b. Place the test cylinder on the lower bearing block and carefully align the axis of the cylinder with the center thrust of the spherically seated block.

c. Rotate the spherically seated block immediately prior to testing to assure freedom of movement. The blocks shall be designed to be rotated freely and tilted at least 4° in any direction.

3. Loading - Apply the load continuously and without shock.

a. Moist cured cylinders must be kept in a moist condition prior to testing. Cylinders may be kept outside of the moist room for up to three hours prior to testing by covering the cylinders with a moist absorbent fabric in an environment between 20 to 30°C (68 to 86°F).

b. For testing machines of the screw type, the moving head shall travel at a rate of approximately 1 mm (0.05 in.) per minute when the machine is running idle. For hydraulically operated machines, the load shall be applied at a rate of movement (plates to crosshead measurement) corresponding to a loading rate on the cylinder within the range of 0.15 to 0.35 MPa/s (20 to 50 psi/s).

c. During the application of the first half of the anticipated loading phase a higher rate of loading is permitted.

d. Make no adjustment in the rate of movement of the plates at any time while a cylinder is yielding rapidly immediately before failure.

e. When loads are indicated on a dial, observe the movement of the pointer during loading operation. When the pointer stops advancing, consider the cylinder in failure. Remove the load and record the reading from the dial. When loads are indicated on a digital readout

machine, the cylinder is considered to be in failure when there is no further increase in readout or peak load is achieved. Remove the load and record the reading from the readout.

f. If a cylinder does not attain the load required by specifications prior to failure, it shall be broken to complete failure and the type of break, as classified in Figure 1, shall be noted and recorded.

g. Should it become apparent during loading operations that the capping compound used is breaking before the cylinder reaches failure, it should be assumed that the cap is defective. The loading procedure shall then be discontinued and the cylinder removed and recapped in accordance with step V.C.2. The load shall again be applied until failure is reached.

VI. Calculations

A. Calculate the compressive strength of the cylinder to the nearest 0.1 MPa (10 psi) by dividing the maximum load carried by the cylinder during the test, as indicated by step V.D.3.e, by the average cross-sectional area of the cylinder or 18,258 mm^2 (28.3 in^2) if applicable.

Average diameter example:

Given: Lot 014, Batch Number 2

Sample No.	Dia. 1, mm	Dia. 2, mm
14-3A	152.75	153.75

$$\text{Avg. diameter (D)} = \frac{\text{Diameter1} + \text{Diameter2}}{2}$$

$$= \frac{152.75 + 153.75}{2} = \frac{306.50}{2} = 153.2$$

$$D = 153.2 \text{ mm}$$

Note 2: *In the above example, the average diameter is not within the range of 152.4 ± 0.50 mm (6.0 ± 0.02 in.), thus giving a larger cross-sectional diameter. This cylinder does not conform to the requirements for using the standard cross-sectional area. Therefore, a calculated cross-sectional diameter must be used in place of the standard cross-sectional area.*

Determination of cross-sectional area (A):

$$A = \frac{\pi D^2}{4}$$

where:

D = average diameter, mm (in.)
π = 3.1416, constant
4 = constant

example:

$$\frac{\pi (153.2^2)}{4}$$

$$= \frac{\pi (23\ 470.24)}{4}$$

$$= \frac{73\ 733.93}{4}$$

$$= 18\ 433.48$$

$$A = 18\ 433$$

Determination of compressive strength (C):

$$C = \frac{A}{B} \times 1000$$

where:

A = force, kN (lbf)
B = cross-sectional area, mm^2 ($in.^2$)
C = compressive strength, MPa (lb/in^2)
1000 = constant

Note 3: *The above equation and example is for metric units to be used when force is given in kN. If English units are used the constant one thousand (1000) shall not be used.*

example:

A = 528
B = 18258

$$\frac{528}{18258} \times 1000$$

$$= 0.028\ 918 \times 1000$$

$$= 28.918$$

$$C = 28.9$$

B. When the compressive strength of any individual cylinder in a set of three is more than 15 percent above or below the average strength for a set, that individual test result shall be considered doubtful and the cylinder considered an outlier. The compressive strength of an outlier shall not be used in the computation of the average compressive strength for acceptance and pay purposes. To determine if any single test is an outlier that should not be considered for acceptance and pay purposes, the following method shall be used:

1. Compute the arithmetic average of the values in a set $\bar{x}$ to the nearest 0.1 MPa (1 psi) using the following equation:

$$\bar{x} = \frac{x_1 + x_2 + x_3}{3}$$

where:

x_1, x_2, and x_3 = individual comp. strengths of a set of three cylinders, MPa (psi)

3 = constant (no. of cylinders)

example:

Sample No.	Strength, MPa
14-3A	26.8
14-3B	28.1
14-3C	26.1

$$\bar{x} = \frac{26.8 + 28.1 + 26.1}{3}$$

$$= \frac{81.0}{3}$$

$$= 27.0$$

$$\bar{x} = 27.0$$

2. Compute the quantities $0.85\bar{x}$ and $1.15\bar{x}$ to the nearest 0.1 MPa (1 psi).

$0.85\bar{x} = 0.85(27.0) = 22.95 = 23.0$
$1.15\bar{x} = 1.15(27.0) = 31.05 = 31.0$

3. If any individual strength is greater than $1.15\bar{x}$ or less than $0.85\bar{x}$, discard it and average the strengths of the other two cylinders to determine the strength of the set.

Note 4: In the above example, all cylinder test results are within the range of $0.85\bar{x}$ and $1.15\bar{x}$; therefore, there are no outliers.

4. When the individual strengths of 2 cylinders are greater than $1.15\bar{x}$ or less than $0.85\bar{x}$, discard them. The strength of the remaining cylinder shall represent the strength of the set.
5. When the individual strengths of all cylinders in a set are greater than $1.15\bar{x}$ or less than $0.85\bar{x}$, no average compressive strength for the lot shall be calculated. In this case, a further evaluation of the concrete represented shall be made.

C. When a lot consists of two sets of cylinders, the average compressive strength for the lot shall be the arithmetic average of the average compressive strengths obtained for the two sets of cylinders.

VII. Report

A. The report shall include the following:
1. Sample Number (Specimen identification).
2. Area of the cylinder to the nearest 1 mm^2 (0.1 $in.^2$).
3. Maximum load to the nearest 2 kN (500 lbf).

4. Compressive strength to the nearest 0.1 MPa (10 psi).
5. Type of fracture.
6. Defects in either specimen or cap.
7. Age of specimen in days.

VIII. Normal Test Reporting Time

Normal test reporting time is 4 hours from time of test.

MATT MENU SELECTION - 17

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Louisiana Department of Transportation and Development

STRUCTURAL CONCRETE TESTS

(DOTD TR 226 & TR 230)

Project No. 450-30-0025 Material Code 452 Lot No. 014

Date Sampled 07-29-92 Submitted By 0722 Quantity 4000.0

Purpose Code 3 (1. Quality Control, 2. Verification, 3. Acceptance, 4. Check, 5. Resample, 6. Source Appr., 7. Design, 8. Indep. Assur., 9. Preliminary Source Test) Plant Code 0723 Spec Code 1

Mix Design No. 001 Admixture: Air Y (Y = Yes, N = No)

Date Received (lab) 07-30-92

Remarks 1 Used in Span 5

WR-NS N

Item No. 805

WR-SR N

Cylinders Made By DOTD Inspector Acceptance Tests By DOTD Inspector

Batch Number 02 95 mm Acceptance Tests

Date Tested 08-26-92 Slump, in. (TR 207) 3.75 Air Content, % (TR 202) 4.5

Sample No.	Laboratory No.	Cond.	Break	Age Days	Diam.	Area	Maximum Load	Strength
14-3A	07-162533	1	1	28	152.4	18258	528	28.9
14-3B	07-162534	1	1	28	152.4	18258	530	29.0
14-3C	07-162535	1	1	28	152.4	18258	552	30.2

Time Made: 10:00 AM Critical Strength: Low 25.0 High 33.8 Batch Avg. 29.4

Batch Number 18 89 mm Acceptance Tests

Date Tested 08-26-92 Slump, in. (TR 207) 3.50 Air Content, % (TR 202) 4.0

Sample No.	Laboratory No.	Cond.	Break	Age Days	Diam.	Area	Maximum Load	Strength
14-4A	07-162536	1	1	28	152.4	18258	528	28.9
14-4B	07-162537	1	1	28	152.4	18258	560	30.7
14-4C	07-162538	1	1	28	152.4	18258	542	29.7

Time Made: 2:15 PM Critical Strength: Low 25.3 High 34.3 Batch Avg. 29.8

Break Codes: 1 = Satisfactory, 2 = Unsatisfactory

Cond. Codes: 1 = Good, 2 = Improperly Made, 3 = Damaged, 4 = Frozen

Average Strength for Lot 29.6

% Pay 100

Tested By CD

Checked By KC

Remarks 2

Approved By District Lab Engineer

Structural Concrete Test
Figure 1